but we describe them differently. Caloric has a physical existence, instead of being merely the logarithm of the probability of a complexion. In common with many experimentalists, I can not help feeling that we have everything to gain by attaching a material conception to a quantity of caloric as the natural measure of a quantity of heat as opposed to a quantity of heat energy. In the time at my disposal I could not pretend to offer you more than a suggestion of a sketch, an apology for the possibility of an explanation, but I hope I may have succeeded in conveying the impression that a caloric theory of heat is not so entirely unreasonable in the light of recent experiment as we are sometimes led to imagine.

H. L. CALLENDAR

THE PROBLEM OF MECHANICAL FLIGHT

HISTORICAL RÉSUMÉ

THE scientific period in aviation began in 1809 when Sir George Cayley published in *Nicholson's Journal* the first complete mechanical theory of the aeroplane, in which he put clearly in evidence the fundamental principle of sustention obtained by velocity. This memoir passed unnoticed until unearthed some sixty years later by Pénaud. Following Cayley there was a long unfruitful interval in which fell the projected aeroplane of Henson in 1842–43, the attempts at gliding by Le Bris in 1856, and the biplane gliders of Wenham in 1866. At the end of the Franco-Prussian war interest in heavier-than-air flying machines was revived, and the Société française de Navigation aérienne was from 1872 on composed of a number of investigators engaged in the conquest of the air. The history of their endeavors is found in "L'Aéronaute." Among them was Alphonse Pénaud, a young mechanic whose early death prevented him from pushing his researches to their logical end. Pénaud was less isolated than Cayley and one of his memoirs was crowned by the Académie des Sciences. He constructed the first toy aeroplane, with the propeller in the rear and driven by a rubber band. This apparatus flew for an appreciable time, *utilizing motive energy which it carried with it*, and this property differentiates very sharply the experiment of Penaud from those of his predecessors, in which was realized only a fall more or less retarded by the air.

The German Lilienthal followed Penaud, and from 1891 studied the equilibrium, maneuvering and landing of gliders, falling to his death on his two thousandth flight, August 9, 1896. In this country the French engineer Chanute and the American Langley had meanwhile been experimenting and developing the laws of aerodynamics, Langley's work going as far back as 1887 and continuing until his unsuccessful attempts at flight in 1903. In 1891 he published[1] the results of his researches, and definitely stated that it was possible to construct machines which would give such velocity to inclined surfaces that bodies indefinitely heavier than air could be sustained upon it and moved through it with great speed.

By the end of the nineteenth century efforts to build aeroplanes had become numerous. Sir Hiram Maxim in England and Ader in France both constructed machines and made attempts to fly them. Maxim built in 1890–95 a flying machine with 557 square meters of surface and 3,640 kilograms weight, which was damaged before leaving the ground and abandoned. The "Avion" of Ader was tested on the field of Satory in 1897 before the representatives of the French War Department, but its performance led the department to withdraw its support and experiments were discontinued. Langley as early as 1896 had designed and built a small steam-driven model aerodrome weighing about 13 kilograms, and on May 6 of that year he flew it some 1,200 meters over the waters of the Potomac. The quarter-size model of his large man-carrying aerodrome flew successfully about 1,000 feet near Widewater, Va., on August 8, 1903, but the large machine itself, carrying Mr. Manly, was injured in launching

[1] "Experiments in Aerodynamics," Smithsonian Contributions to Knowledge, Vol. 27, 1891.

from the top of a houseboat on October 17, 1903, and wrecked in a second attempt on December 8 of that same year.

With this ended sixteen years of effort on the part of Langley to attain mechanical flight, and his long period of fruitful scientific achievement closed with failure due primarily to lack of funds. The report[2] of Major Macomb to the War Department concerning the tests made on the Potomac is interesting and illuminating.

After describing the attempted launching on October 7 and the subsequent wrecking of the great aerodrome on December 8, Major Macomb closes with the following paragraphs:

Having reached the present stage of advancement in its development, it would seem highly desirable, before laying down the investigation, to obtain conclusive proof of the possibility of free flight, not only because there are excellent reasons to hope for success, but because it marks the end of a definite step toward the attainment of the final goal.

In the meantime, to avoid any possible misunderstanding, it should be stated that even after a successful test of the present great aerodrome, designed to carry a man, we are still far from the ultimate goal, and it would seem as if years of constant work and study by experts, together with the expenditure of thousands of dollars, would still be necessary before we can hope to produce an apparatus of practical utility on these lines.

The War Department had made two allotments of $25,000 each to Langley to further his experiments, one in 1898 and the second in 1899. The large aerodrome was completed in July of 1903, the long delay being due to Langley's inability to secure a suitable motor, which he finally had to design. The tests referred to above were made in the fall of 1903 and on March 3, 1904, the Board of Ordnance and Fortifications stated[3] that it was "not prepared to make an additional allotment at this time for continuing the work." All material was left in Langley's possession for such future experiments as he might wish to make.

[2] Langley, "Memoir on Mechanical Flight," p. 276, Smithsonian Contributions to Knowledge, Vol. 27, 1911.

[3] Langley, "Memoir," p. 278.

On November 14, 1908, the board again reported:[4]

Doctor Langley considered it desirable to continue the experiments, but the Board deemed it advisable, largely in view of the adverse opinions expressed in Congress and elsewhere, to suspend operations in that direction.

The persistent misrepresentations of the public press caused Langley to publish the following statement.

SMITHSONIAN INSTITUTION,
WASHINGTON, D. C.,
August 19, 1903.

TO THE PRESS: The present experiments being made in mechanical flight have been carried on partly with funds provided by the Board of Ordnance and Fortification and partly from private sources, and from a special endowment of the Smithsonian Institution. The experiments are carried on with the approval of the Board of Regents of the Smithsonian Institution.

The public's interest in them may lead to an unfounded expectation as to their immediate results, without the explanation which is here briefly given.

These trials, with some already conducted with steam-driven flying machines, are believed to be the first in the history of invention where bodies, far heavier than air itself, have been sustained in the air for more than a few seconds by purely mechanical means.

On my previous trials, success has only been reached after initial failures, which alone have taught the way to it, and I know no reason why the prospective trials should be an exception.

It is possible, rather than probable, that it may be otherwise now, but judging them from the light of past experience, it is to be regretted that the enforced publicity which has been given to these initial experiments, which are essentially experiments and nothing else, may lead to quite unfounded expectations.

It is the practice of all scientific men, indeed of all prudent men, not to make public the results of their work till these are certain. This consideration, and not any desire to withhold from the public matters in which the public is interested, has dictated the policy thus far pursued here. The fullest publicity, consistent with the national interest (since these recent experiments have for their object the development of a machine for war

[4] Langley, "Memoir," p. 279.

purposes), will be given to this work when it reaches a stage which warrants publication.

(Signed) S. P. LANGLEY

Like many men of his kind Langley seems to have had that passionate sense of privacy which resents alike the curiosity of the public and the sensationalism of the newspapers. The antagonistic attitude of the press gave a character of finality to experiments which to Langley himself were but members of a long series bringing him each year nearer the goal. Had his health and strength remained to combat the hostility of press and public, he would in all probability have gone on to success, undeterred by criticism and misunderstanding. To such patient and unremitting labor as his is owed the accomplished fact of mechanical flight. He began his investigations at a time when even progressive men of science thought flying a wild dream, and a large part of that exact investigation which transformed vague ideas into scientific knowledge is due directly to him. His work is measured not solely by his contributions, but much more by the unswerving advance in a field of scientific inquiry in which no road was marked.

The spirit of the man is made evident by his steadfast refusal to entertain propositions made him to assist in the development of the aerodrome provided arrangements were made for later commercialization. He had given his time and energy without hope of remuneration, and even when no assistance could be obtained from any other source and success seemed but a step away, he could not bring himself to capitalize his scientific work, although his age was such that any delay in achieving success increased the probability of his not living to see it. He died February 27, 1906, about two years before the Wright brothers astonished the world by their feats in sustained flying in 1908.

II

FUTURE OF THE AEROPLANE

The Problem of Velocity.—The mechanical theory of the behavior of the aeroplane is built on the principle that in steady horizontal flight the normal thrust on the sustaining surface is proportional to the area, to the square of the relative velocity, and to the sine of the angle of attack, or:

(1) $$F = kSV^2 \sin i,$$

where, *for small values of* i, k is a constant for a given surface under constant atmospheric conditions, S is the area of the sustaining surface, V its velocity relative to the air stream, and i the angle of attack. For uniform horizontal flight i equals the fixed inclination of the sustaining surface to the horizontal axis of the aeroplane, and is a constant of the machine.

The vertical component of this normal thrust—*the lift*—must equal the weight of the whole machine, and denoting the lift by L and the weight by W, there follows:

(2) $$L = W = kSV^2 \sin i \cos i = kSV^2 i \text{ (nearly)}.$$

The *sustaining resistance* R is given by the horizontal component of the normal thrust, whence:

(3) $$R = kSV^2 \sin^2 i = kSV^2 i^2 \text{ (nearly)}.$$

The power P required to overcome the sustaining resistance R is:

(4) $$P = RV = kSV^3 i^2.$$

From (2) and (4) we have:

(5) $$V^2 = W/kSi, \quad P = W^2/ksV.$$

These two relations lead to the very important result that the *velocity of sustention* V increases as the angle of attack decreases, and the power required to drive the sustaining plane against its own resistance decreases as the velocity increases. The advantage of flying at high velocity and "close to the wind" is at once evident.

In these relations, however, the resistance offered by the motor and its accessory parts including the framework—*the passive resistance*—has been neglected. The power required to overcome this is proportional to the cube of the velocity and the "equivalent surface" presented to the air stream, and is enormously increased at high velocities. It is at once evident that for a given machine there is a maximum velocity beyond which the motor can

not drive it. The *problem of velocity* may then be stated as follows: Required a motor which shall be capable of driving itself and accessory parts, including framework and sustaining surface, against its own resistance at high velocity. Undoubtedly the problem so stated is too simplified, but the motor must be capable of developing at least that power.

The solution of the problem does not lie in the construction of larger motors homothetic to those now in use, for the "equivalent resisting surface" is increased at the same time that the power is augmented, and if the calculated attainable speed be based on the assumptions of power proportional to weight, weight proportional to cube of linear dimensions, and "equivalent resisting surface" proportional to square of linear dimensions, then the power must be increased 512 fold in order to double the speed. In particular, if a motor developing 100 horse power could drive an aeroplane at a speed of 100 kilometers an hour, a homothetic motor developing 800 horse power would, under the conditions stated above, drive its aeroplane at 126 kilometers per hour.

These assumptions are at the present time well within the range of consideration, and give a general idea of what to expect along the line of motor development.

The solution of the problem may, however, be in quite another direction: in the construction of steam line body forms for the aeroplanes of the future. Stream line forms offer a minimum resistance at high velocities, and their attainment is the immediate problem of the future so far as the development of high speeds is concerned. The architecture of the aeroplane is thus seen to be of paramount importance, and it is in that direction that future advance may be looked for.

The Problem of Stability.—More important than the attainment of high velocity is the realization of stability in flight. At the present time it is to a very large extent dependent on the personal skill of the aviator, and however great this may become, it is highly desirable that the aeroplane should be rendered *automatically stable* in straightaway flight at least, if for no other reason than to leave the aviator free to attend to such other matters as may legitimately engage his attention.

The distribution of the mass of the aeroplane about its center of gravity is at once felt in the sensitiveness of the response which the machine accords to disturbing forces. If the aeroplane be disturbed by some external force so that the angle of attack becomes α instead of i, it will oscillate about its position of equilibrium under the equation:

$$I\frac{d^2\alpha}{dt^2}=\sigma V^2(\alpha-i)-2hV\frac{d\alpha}{dt}, \tag{6}$$

where I is the moment of inertia about a horizontal gravity axis perpendicular to the direction of motion, and σ and h are constants. This equation shows at once that if the sustaining plane pitches slightly, the *initial* oscillation will be the more violent the smaller the value of I and hence the closer the heavy masses to the center of gravity G. A more complete discussion of equation (6), however, shows that the motion defined by it, under the initial conditions

$$\alpha_0+i,\quad \left(\frac{d\alpha}{dt}\right)_0=0,\quad t=0,$$

dies down the more rapidly the smaller the value of I, and hence the initial disadvantage of violent oscillation is more than compensated by the rapidity with which these oscillations disappear under *damping*. From the standpoint of stability the best type of machine would seem to be that in which the heavy masses are concentrated in the neighborhood of the center of gravity. Such a distribution, however, produces a machine very sensitive to external disturbances and too small a value of I will produce too great an initial value of α, and equation (6) will no longer define the motion. Theoretically, at least, under equation (6) the moment of inertia of a given machine might be made so small that the damping would produce a periodic motion, but practically the initial displacement would then be so large for a small force that the orientation would no longer be in the neighborhood of the equilibrium orientation. It is necessary that some

method of keeping the initial displacement small under a disturbing force be devised, but it is equally undesirable that the moment of inertia be materially increased by the introduction of the stabilizing device. This consideration alone would serve to discard all methods of stabilization making use of heavy masses, such as heavy gyroscopes or pendulums, and an effective stabilizing device would have to call into play the stabilizing surface by means of a mechanism of transmission operated by a light mass sensitive to light disturbing forces, such as a small but rapidly rotating gyroscope. Direct stabilization by a heavy pendular mass, for instance, is a purely chimerical procedure.

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EARLY MAN IN SOUTH AMERICA

FIVE years ago the Bureau of American Ethnology published a bulletin on Skeletal Remains Suggesting, or Attributed to, Early Man in North America, based on the researches of Dr. Ales Hrdlička, Curator of Physical Anthropology in the U. S. National Museum. There is to appear shortly in similar form, under the title of Early Man in South America, a résumé of the investigations of Dr. Hrdlička, in collaboration with Mr. W. H. Holmes, head curator of the Department of Anthropology in the U. S. National Museum, Mr. Bailey Willis, of the U. S. Geological Survey, and Messrs. Fred. Eugene Wright and Clarence E. Fenner, of the Geophysical Laboratory of the Carnegie Institution of Washington.

Even before the completion of his report on ancient man in North America, Dr. Hrdlička became interested in the evidence bearing on the corresponding problem in South America, and subsequently, at the suggestion of Mr. W. H. Holmes, he was sent by the secretary of the Smithsonian Institution to visit Argentina for the purpose of making a study at first hand of the available material and an investigation of the most promising regions.

In view of the important position occupied by geology in studies of this nature, Mr. Bailey Willis of the U. S. Geological Survey was chosen to accompany Dr. Hrdlička.

The chief objects of the expedition were: the examination of the skeletal remains relating to early man, in Brazil and Argentina; the study of the principal localities and deposits from which these finds came; and, if possible, the collection of osseous, archeologic and other specimens bearing on the subject of man's antiquity. It was hoped that thorough investigation on the ground would enable the explorers to form more definite conclusions concerning the finds than the literature relating to them warranted, and that possibly by means of new discoveries additional light would be thrown on the whole subject of early man in South America, especially in Argentina.

The party reached Argentina early in May, 1910. Dr. Hrdlička spent two months in that country, while Mr. Willis remained somewhat longer, nearly all of this time being given to the researches recorded in the report. The work was greatly facilitated by several of the local men of science, and the authors express warm appreciation for the valuable assistance thus rendered. During the first part of the stay in Argentina, Dr. Hrdlička devoted his time to the study of the available skeletal material attributed to ancient man, found in the various local museums, while Mr. Willis examined the various samples of baked earth, and other objects believed to have been associated with the activities of prehistoric man. Several localities in Buenos Aires where local exposures could be studied, including the drydock where the "Diprothomo" skull had been found some time before, were carefully examined. On May 24 the party set out for the coast where important specimens had been discovered, and a few days later were joined at Mar del Plata, by the late Professor Florentino Ameghino and his brother Carlos, who assisted the expedition materially, accompanying Dr. Hrdlička and Mr. Willis for more than three weeks from place to place on the coast, and to several inland points of interest.

After the completion of this general survey, Dr. Hrdlička visited the valley of the Rio Negro whence came several fossil crania many years ago, while Mr. Willis proceeded to